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HEAT PIPE COPPER VAPOR LASER

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HEAT PIPE COPPER VAPOR LASER

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This report describes the development of a heat pipe copper vapor laser with radial discharge excitation and operating temperatures to 2000°C.

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HEAT PIPE COPPER VAPOR LASER
SEMI-ANNUAL TECHNICAL REPORT
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I. TECHNICAL REPORT SUMMARY

This report summarizes the progress made thus far to demonstrate a heat pipe copper vapor laser. The first part of the program involved the design, construction, and operation of an optical cell containing the copper vapor in the heat pipe mode at 2000°C. The second part of the program involved the development of two radial discharge electrode structures compatible with the heat pipe geometry and suitable for the excitation of a population inversion in the atomic copper vapor. Thus far, in the third part of the program one of the radial discharge electrode configurations has been incorporated with the heat pipe cell and laser action has been demonstrated with the cell operated in the heat pipe mode.

Problems remain in the fabrication of the capillary structure (used to return the liquid copper to the evaporator) to maintain structural and dimensional integrity at the higher temperatures.

All of the major technical objectives have been attained; namely, the development of a copper vapor cell operating in the heat pipe mode at temperatures to 2000°C, the development of radial discharge configurations, and demonstration of laser action in the heat pipe. Solutions to the remaining problem and a preliminary study of the heat pipe copper vapor laser is expected to be completed in the remaining month of the contract.

II. HEAT PIPE COPPER VAPOR CELL

In the first part of the program a cell containing copper vapor was operated in the heat pipe mode at temperatures to 2000°C. The cell was constructed of a graphite tube with a 50 micron thick foil as a liner to the inner wall of the graphite tube. The inside diameter of the cells ranged between 1.86 and 2.5 cm. Tungsten screen was rolled into three layers and inserted into the tungsten-lined tube. This screen provided the capillary structure which served to return the liquid copper condensate back to the center of the cell. Experiments were carried out with a variety of screen mesh sizes and wire diameters. Mesh sizes between 50 and 120 and wire diameters of 50 and 75 microns were employed.

The cells were loaded with copper wire or powder sufficient to saturate the capillary structure and inserted into a three zone vacuum furnace with graphite resistance heating elements. The central element heated the center of the heat pipe which served as the copper evaporator. The outer heaters were used to heat the non-condensible gas (argon) in the condenser regions of the heat pipe. This gas was introduced to control the operating temperature of the heat pipe. The possibility of heating the non-condensible gas in the region of the vapor-gas interface was provided in the event that gas phase condensation would occur resulting in droplet formation. This, however, has not been observed.

Operation in the heat pipe mode became dramatically evident above 1650°C. The temperature variation along the axis of the cell was measured to be less than ± 10°C at 1700°C and ± 15°C at 2000°C. The length of the vapor zone was typically 4 times greater than the length of the heater element and was measured to be roughly 82 cm. The volume of vapor was 250 cm^3. When the copper vapor pressure reached that of the non-condensible gas, a further increase in the electrical heater power did not result in an increase in temperature but only in an increase in the rate of evaporation of the copper. When this point has been reached, it was possible to reduce the power into the heater to such a level where the heat input just balanced that lost. Very little additional power above this point was required to maintain the vapor. An increase in the non-condensible gas pressure caused an increase in the vapor pressure and temperature as expected.

There was recurring problem in the operation of the heat pipes. During the operation of the device, slight separation of the layers of screen which comprised the capillary structure caused a "puddling" of the liquid copper and stopped the capillary pumping at that region. The accumulation of the liquid copper at this point increased the distortion of the wick. This process continued until in extreme cases the wick obscured the optical path through the cell. Inserting a tungsten wire coiled to exert a radial outward force against the screen did improve the situation. Further improvements are expected if the wrapped layers of screen were swaged or diffusion bonded.

III. RADIAL DISCHARGE CONFIGURATIONS

The cylindrical heat pipe with its electrically conducting walls prevented the formation of an axial discharge. Various radial geometries were investigated as an alternate geometry. In particular, two configurations have been developed. One configuration consisted of two concentric cylinders while the second consisted of two concentric cylinders with an axial slot cut in the inner electrode. The discharge occurs, in the first case, in the annular region between the two electrodes. In the second case, that of the radial hollow cathode configuration, the discharge occurs in the interior of the hollow cathode as well as in the space between the anode and cathode in the vicinity of the slot.

These configurations were first developed and studied in copper discharge tubes with argon and helium as the discharge medium. A variety of diameters were employed, the largest tube having a 5 cm anode. Lengths up to two meters long were studied. In order to verify that the discharge was occurring uniformly and simultaneously down the entire length radial sight ports located every 5 cm were built in the anode. The spontaneous emission from the excited rare gas at several axial positions were simultaneously recorded on an oscilloscope whose horizontal sweep was initiated by the leading edge of the discharge current pluse. It was found that the discharges were axially uniform. The light emission from extreme

ends of the tube were temporally coincident to less than 5 nsec and the light intensity from both regions were equal within 10%. These results held from 0.5 to 20 torr. Higher pressures were not as yet investigated.

The general criteria for the production of radial discharges are (1) the desired potential difference must be attained in a time which is short compared with the arc formation time, and (2) the applied voltage should be very much greater than the minimum breakdown voltage for the annular anode-to-cathode gap. These criteria are, in fact, related in that the maximum potential attainable between the electrodes increases as the voltage rise time decreases.

IV. THE HEAT PIPE COPPER VAPOR LASER

The tungsten components which comprise the heat pipe capillary structure were combined with the slotted hollow cathode electrodes fabricated from high density graphite. This device was operated as a gas loaded heat pipe to temperatures of 1800°C and laser action was obtained. Laser power measurements, extension of the operating temperature to 2200°C, and a preliminary study of the heat pipe copper vapor laser are under way.